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INTERPRETATION OF CERTAIN PHENOMENA OF THE MAGNETOSPHERE BY PLASMA INSTABILITIES

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INTERPRETATION OF CERTAIN PHENOMENA OF THE MAGNETOSPHERE BY PLASMA INSTABILITIES*

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by Robert Stefant
and Guy Vasseur

R. Gallet [1] interprets certain forms of VLF emission by interaction of a beam of charged particles (electrons) with the magnetospheric plasma. J. Neugeld and H. Wright [2] have also studied the interaction of a beam of particles (electrons and ions) with a plasma, whose Denisse and Lacroix characteristic parameter [3]

$$\Lambda = \Omega_e^2/(\Omega_{\shortparallel}\,\Omega_i)$$

varies from 1 to 10^6 (which includes the case of the magnetosphere where $10^2 < A < 10^6$). We have reconsidered the bases of Neufeld and Wright's calculations with the view of interpreting certain natural ULF emissions [4] on one hand, and the case of ionization distributed along the lines of force of the Earth's magnetic field, on the other [5, 6].

We consider a cold plasma, composed of electrons and only one kind of ion, and placed in the Earth's magnetic field B. For a given angle φ between the field B and the wave vector **k**, there exist four propagation modes [4]. In particular, for strictly transverse waves and at $\varphi = 0$, the dispersion equation is written

$$F(\omega, k) = \omega^2 - k^2c^2 - \frac{\Omega_e^2\,\omega^2}{(\omega - \Omega_{\shortparallel})\,(\omega + \Omega_i)}. \qquad (1)$$

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* Interprétation de certains phénomènes de la magnétosphère par des instabilités de plasma.

Assume then a homogenous, indefinite, homokinetic beam of electrons and protons, of low density relative to the plasma it crosses. Their velocity **v** is inclined to the field B by an angle ψ. This beam has two natural frequencies — the Langmuir and the gyrofrequency, which are subject to Doppler effect on account of the velocity **v**. Limiting ourselves to waves associated to gyrofrequency and to vector **k** parallel to B, the beam's dispersion equation corresponds to two purely transverse pulsation waves :

$$\omega = kc\beta\cos\psi \mp \Omega_{H,i}(1-\beta^2)^{\frac{1}{2}} \qquad \beta = \frac{v}{c} \qquad (2)$$

The interaction of the beam with plasma is represented in Fig. 1 by the intersection of representative lines of the equation (1) in the coordinates ω, k : a, b for the electron beam, c, d for the ion beam, and of curves e, f for the plasma, which are representative of the equation (2). J. Neufeld and H. Wright have shown that a criterion of instability made to intervene the sign of $\partial F/\partial\omega$. But they studied only of the two permitted Doppler waves (corresponding to the curve a for the electrons and to the curve d for the ions).

For a beam of electrons (a and b) examination of the figure and above criterion show that two frequencies are emitted at points a_1 and b_1, such as $-\Omega_i < \omega_{a_1} < 0$ and $0 < \omega_{b_1} < \Omega_H$. At any rate, we obtain the same result starting from the criterion of instablity given by Lepechinsky and Rolland [5].

Only strongly relativistic electrons can induce by this mechanism an emission frequency sensibly different from Ω_i or Ω_H. It would not be the same for the excitation of space charge waves by a very diluted electron beam.

For the proton beam, two, four or six frequencies can be excited depending upon the value of β.

The point c_1 for the line c corresponds to a wave for which $-\Omega_i < \omega < 0$, $|\omega/\Omega_i| \ll 1$[9]. The following table summarizes the different possibilities for the other emissions of the line $\underline{d}$, depending upon the value of β.

We see that this plasma-beam system gives way to an emission of extremely low frequency ($|\omega/\Omega_i| < 10^{-3}$) and of another, or three frequencies, of which two can be very close, depending upon the value of the parameters.

TABLE 1

β	o	$\sqrt{\frac{7}{A\cos^2\psi}}$		$\sqrt{\frac{\Omega_H}{4\Omega_i A\cos^2\psi}}$	
figurative points	d_1		d'_1 d'_2 d'_3		d'_1
ω	1 émission $\omega \simeq \Omega_H$	1 émission $\frac{\Omega_H}{2} < \omega < \Omega_H$ 2 very close emissions $\omega \simeq 2\Omega_i$	3 émissions	1 émission $\omega \simeq 0$ 2 very close emissions $\omega \simeq \frac{\Omega_H}{2}$	1 émission $\omega \simeq 0$

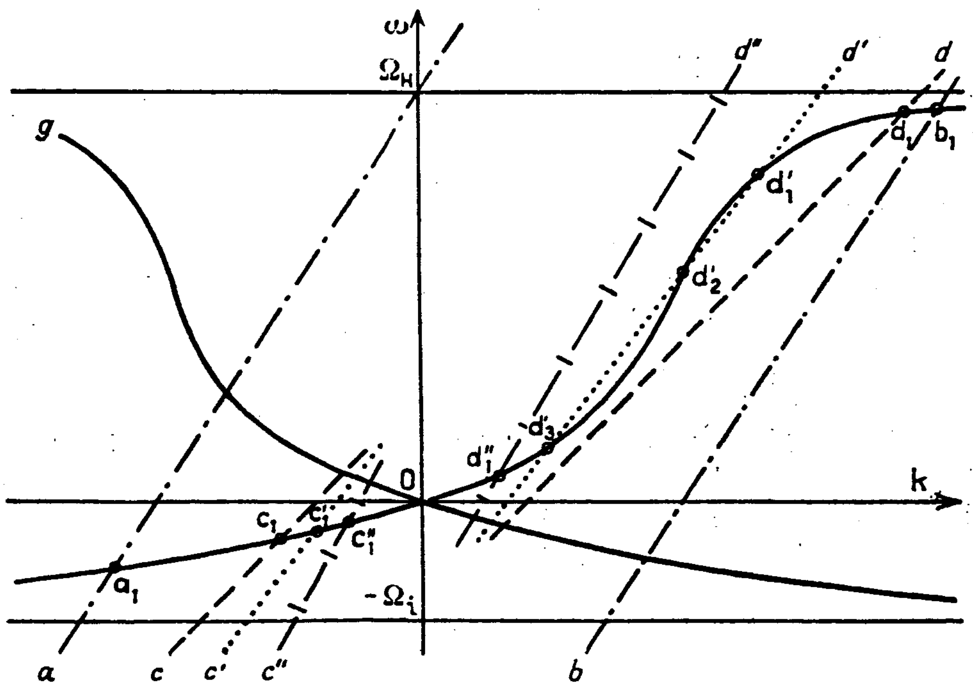

Fig. 1. - Interaction of a plasma [e, f] with a beam of electrons [a, b] or protons [c, d or c', d' or c", d"]

Some of these possibilities provide an interpretation of geophysical phenomena of the above-mentioned type.

***** THE END *****

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[*].- For the comprehension of Fig. 1 we have omitted the additional intersections of the line c with the curve f. This type of interaction is identical to that studied by Gallet for the space charge waves.

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